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NEW TRENDS IN TECHNOLOGY AND THEIR APPLICATIONS: HYDROGRAPHY

Department of Defense requirements for digital nautical chart data: a Defense Mapping Agency perspective

Paper submitted by the United States of America**

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INTRODUCTION

Surface ship navigation is moving into the digital environment. With the Global Positioning System (GPS) providing accurate positioning data, advanced computing systems supplying the horsepower to handle large databases of charting data, and the successful development of DoD standards for the exchange of digital data it is now feasible to develop and deploy electronic chart navigation systems. In the international marine navigation community, this type of system is known as ECDIS (Electronic Chart Display and Information System). Seeing the advantage of ECDIS-supported navigation, the United States Congress recently introduced legislation (the "Maritime Navigation Technology and Research Act of 1992") which calls for the Department of Transportation to develop and implement a plan to ensure continued advancement in such navigation technology.

U.S. NAVY ELECTRONIC CHART REQUIREMENT

Well in advance of this action by Congress, the U.S. Navy formed a team to build, for Navy, an ECDIS using commercial off-the-shelf hardware with in-house software development. This Navy ECDIS, termed AN/SSN-6 NAVSSI, has two primary objectives: processing and distribution of navigation data and the display/manipulation of Digital Nautical Charts (DNCs). In April 1989, Navy submitted a new digital product requirement to DMA, describing the need for the legal replacement of paper nautical charts with a topological structured vector database to support the safe navigation of Navy ships. Since then, Navy engineers and programmers have been working with DMA on the development of this new electronic chart database product, to be called DNC.

The use of DNC is not limited to navigation; other DoD customers require a georelational database including hydrographic features. Requirements have been stated for mission planning, command and control, simulation, and training systems. In these systems, DNC will be used to supply information about hydrographic features that are now graphically/textually presented on paper nautical charts. Data addressing environmental and mission-specific requirements will be provided as additional data layers. DMA validated the new requirement in October 1989 and stated its desire that DNC be the standard digital product for all nautical navigation systems to be developed for the U.S. Navy.

AN/SSN-6 NAVSSI

Navy began installation of NAVSSI aboard the USS Arkansas in 1992 with virtually every ship in the fleet scheduled to receive it by 1997. This installation started with the NAVSSI Real Time Subsystem (RTS) to handle all input/output required for navigation integration and distribution. RTS takes data from GPS, SATNAV (TRANSIT), OMEGA, inertial navigation system, gyro, and speed log to determine ownship position. This position/time information is distributed to other onboard systems including a bridge workstation, combat and weapons systems as well as to other ships, providing a common navigation picture for all elements of the battlegroup. An improvement to NAVSSI is planned for 1994 when all deployed and future units will receive an evolutionary upgrade to incorporate DNC and the tools (software) necessary for automated ship navigation. Once this capability is aboard, the ships will have uniformity of navigation (plotting of ownship position) regardless of ship class and mission. This will be accomplished by the Digital Chart

Subsystem (DCS) which provides man-machine interface functions, chart display/manipulation functions, and accessing of the DNC data. Early NAVSSIs use the Desktop Tactical Computer II (DTC II) which uses the Sun 4/300 SPARC (32-bit) processor. Transition to Tactical Applications Computer (TAC III) is underway. The TAC III is based on the Hewlett Packard 9000-700 series and provides several times the processing power at a lower cost. NAVSSI RTS is rack mounted and located in the forward gyro room. DCS, also rack mounted, is located in the chartroom. A separate bridge workstation provides an additional tactical navigation display at the helm. The DCS is the heart of the ECDIS with a 19 inch CRT display in each unit dedicated to the navigation picture prescribed by the IHO/IMO ECDIS specification. Future plans call for Compact Disc Read Only Memory (CD-ROM) "Jukebox" to contain the DNC CDs covering the ship's mission area. Data from multiple CDs will be loaded directly into cache memory using Vector Product Formant (VPF), the DoD vector data standard, as the internal data structure. Initial tests have shown that this direct use of VPF satisfies operational performance requirements. The Navy applications software will provide tools supporting waypoint navigation, collision and grounding avoidance, and man overboard recovery assistance features. RTS software will be developed using the ADA programming language. DCS software uses C programming language. NAVSSI is being developed by the Naval Undersea Warfare Center, Norfolk, VA and the Naval Command, Control and Ocean surveillance Center, RDT&E Detachment, Warminster, PA under the program management of Space and Naval Warfare Command.

NAVY TEST/EVALUATION ACTIVITIES

Testing of NAVSSI will be conducted as follows:

-Sea trials for basic NAVSSI (no electronic chart functions--data distribution only) consisted of formal testing by an independent Navy test group, Operational Test & Evaluation Force, Norfolk, VA. This testing was successfully completed in November 1992.

-Land Based trials for NAVSSI electronic chart functions were conducted during winter 1993 using the Norfolk, VA test area data on DNC SAMPLER disc. Main objectives included analyzing performance of hardware and software, obtaining feedback on navigation/charting functions and ECDIS issues (i.e., windowing, use of monitors, screen colors, and symbology).

-Sea trials for informal testing of a fully operational NAVSSI are scheduled for the early 1994 aboard a USN ship based in the Norfolk, VA area. The goal of these tests is to evaluate operational effectiveness prior to formal testing.

-Sea trials for formal TECHNICAL EVALUATION/OPERATIONAL EVALUATION of NAVSSI (not to include the ECDIS functions) are scheduled for late spring 1994. The electronic chart functions will be formally tested after NAVSSI has met all basic requirements.

PRODUCT DEVELOPMENT

In order to satisfy this Navy requirement, DMA has begun product development. DNCs will be produced using the same military standard format, VPF, as Digital Chart of the World (DCW), a worldwide database intended to support both military and civil Geographic Information System (GIS) applications. DCW, collected from 1:1 million scale Operational Navigation Charts, was developed through a cooperative effort of the U.S., the United Kingdom, Canada, and Australia. It is accompanied by software for basic display and manipulation.

DNC PRODUCT DEFINITION

Content

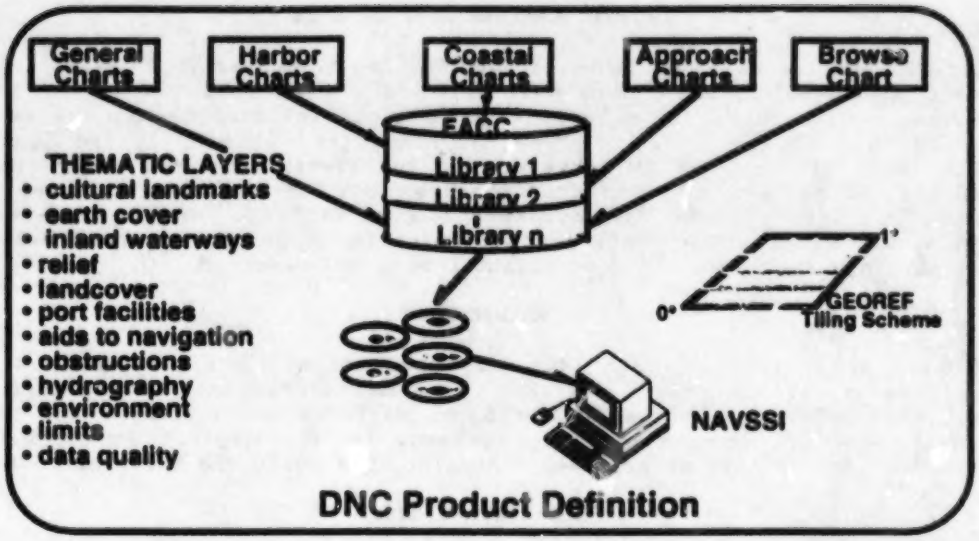
DNC data is thematically layered into 12 related feature classes: cultural landmarks, earth cover, inland waterways, relief, landcover, port facilities, aids to navigation, obstructions, hydrography, environment, limits, and data quality. These are generally the same features contained on a paper nautical chart (see diagram below). Data, functionally equivalent to current harbor, approach, coastal, and general nautical charts, will be stored in different libraries, each library representing a different resolution or level of detail. These libraries are logically organized for storage on CD-ROM into geographic areas called tiles, based on the World Geographic Reference System (GEOREF) Tiling Scheme. Tile sizes vary as a function of the volume of the library. Variable tile sizes are employed as a strategy to improve data transfer rates from CD-ROM. Current tile size for Harbor Library is 15 minutes by 15 minutes, Approach Library is 30 minutes by 30 minutes, and 3 degree by 3 degree for both the Coastal Library and the General Chart Library.

Tiling

DNC will also contain a Browse Library, which serves as an index or overview to the DNC data that is contained on the CD-ROM. It is estimated that total DoD required coverage, equivalent to approximately 4,000 paper charts, will require about 30 CDs.

Access Indices

In addition to the chart data and the Browse (coverage) Library, DNCs also contain several additional tables that can be used to speed up database access and thus enhance performance. The "spatial" indices are used to optimize information retrieval based on geographic or spatial queries. The "thematic" indices are used similarly for theme or feature related queries.



Prototyping Activities

Five prototypes have been completed and evaluated. The first covered Hampton Roads. The second added the entrance to Chesapeake Bay and was developed from six charts to provide harbor, approach, and coastal coverage. A third, added the port of New York and the General Scale coverage between the two ports. It was the first prototype to use the "Feature Attribute Coding Catalog (FACC)" coding structure of the proposed standard developed by the Digital Geographic Information Working Group (DGIWG). The fourth was an updating of the Norfolk area with Notice to Mariner corrections and the addition of coverage for Wallops Island Navy demonstration area. The fifth provided approach coverage for the USCG Vessel Traffic System in Puget Sound, WA. A collection of both prototypes four and five were placed on CD-ROM along with DMA's VPF-VIEW display software and documentation to form a DNC SAMPLER. This disc can be made available for evaluation by contacting HQ DMA, Plans and Requirements Directorate, Mail Stop A-13, ATTN: Mr. Danford, 8613 Lee Highway, Fairfax, VA, 22031-2137, telephone (703) 285-9326.

Production Schedule

Development of a DNC production capability has begun. In addition to in-house production at DMA, the National Ocean Service is building DNCs to satisfy DoD requirements over their area of responsibility. Contract production is also underway with first articles delivered. Production DNCs will be available for DoD use in 1994 when the Navy ships are outfitted with NAVSSI.

PUBLIC AVAILABILITY OF DNCs

Although DNCs are being built to satisfy DoD requirements, it is reasonable to expect a demand to make them available to the general public for civil navigation. While public sale of DNCs is a possibility, becoming a reality depends on the resolution of three major hurdles. First, is the issue of ECDIS legal status: Can it serve as the replacement for the paper charts. Secondly, a mechanism and infrastructure must be in place to keep DNCs current. Lastly, DMA has agreements for exchange of nautical chart information with several nations that maintain copyrights. DNCs cannot be made publicly available until copyright issues are resolved.

MAINTENANCE

Included as a part of both DoD and international maritime authorities' requirements for electronic charting, is a method for maintaining currency; i.e., the application of weekly Notice to Mariners corrections. The IHO is studying methods for maintaining currency to its digital products. It describes, in its current proposed standards, the following three methods.

Interactive Entry

This method involves the interactive application of Notices to Mariners through the use of a toolkit, available on ECDIS. The user typically reads and interprets the printed Notice to Mariners. Using his toolkit, he selects the symbol appropriate to the correction to be applied, identifies the location of the symbol, and adds appropriate textual information that identifies the nature of the correction. This corrective information is saved on hard disk, and when displayed as a readily distinguishable overlay in concert with the chart information on the CD-ROM, provides a corrected version of the required navigation data. This method is viewed as the simplest and least elegant method to implement. It appears to be labor-intensive to apply corrections, easily subject to error, and could add clutter to the screen display.

Semi-automatic Entry

In the semi-automatic entry method, data is electronically entered into the system (via MODEM, floppy disc, etc.). These corrections are processed automatically by the ECDIS and displayed along with the original information stored on CD-ROM. As with the first method, the corrective information is readily distinguishable from the original information. This approach requires structured and machine interpretable information from the producing hydrographic offices.

Automatic Entry

The automatic method of entry, the most rigorous for both producer and end user, requires automatic interpretation of received corrective information. These corrections are applied to the data before it is displayed, such that corrections are indistinguishable from the original data. Data could be

corrected in this manner on a feature-by-feature basis or by the replacement of entire cells. Each of these approaches require periodic distribution of information which must be applied by each user.

These methods are being evaluated by several ECDIS test bed activities both in the U.S. and abroad.

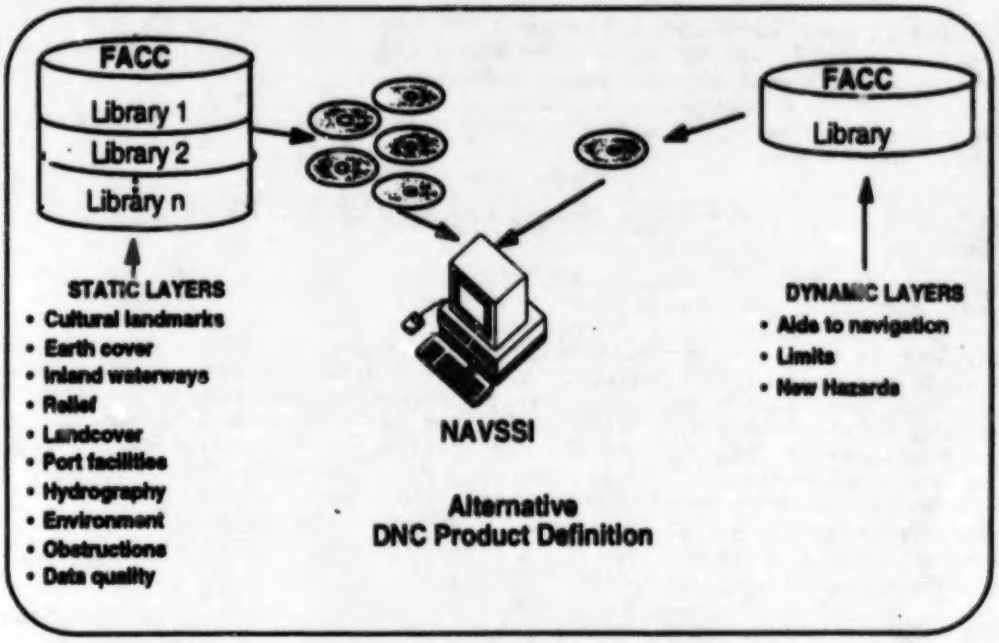
MAINTENANCE ALTERNATIVE

DMA is currently evaluating what could be considered a variation of the automatic-entry approach. In this concept, the DNC product is separated into two products: the first contains only static information, information that may change infrequently (see diagram). DNC static data is distributed as before, organized thematically and by geographic region, and stored in libraries according to the level of detail. The other half of the DNC, Dynamic Layers, is kept current at DMA, through the application, on a weekly basis, of Notice to Mariners information. These dynamic layers, current to the last notice issued and containing worldwide coverage on a single CD-ROM, are distributed to DoD users every one or two weeks. These static and dynamic layers are combined into a single display by the on-board exploitation software, resulting in a current, integrated display.

Rather than having to apply corrections at each user site, the DNC database is kept current by simply replacing one CD for another. Our analysis has shown that 90 percent or greater of notices generated by DMA apply to these dynamic layers containing aids to navigation, obstructions, and navigation limits.

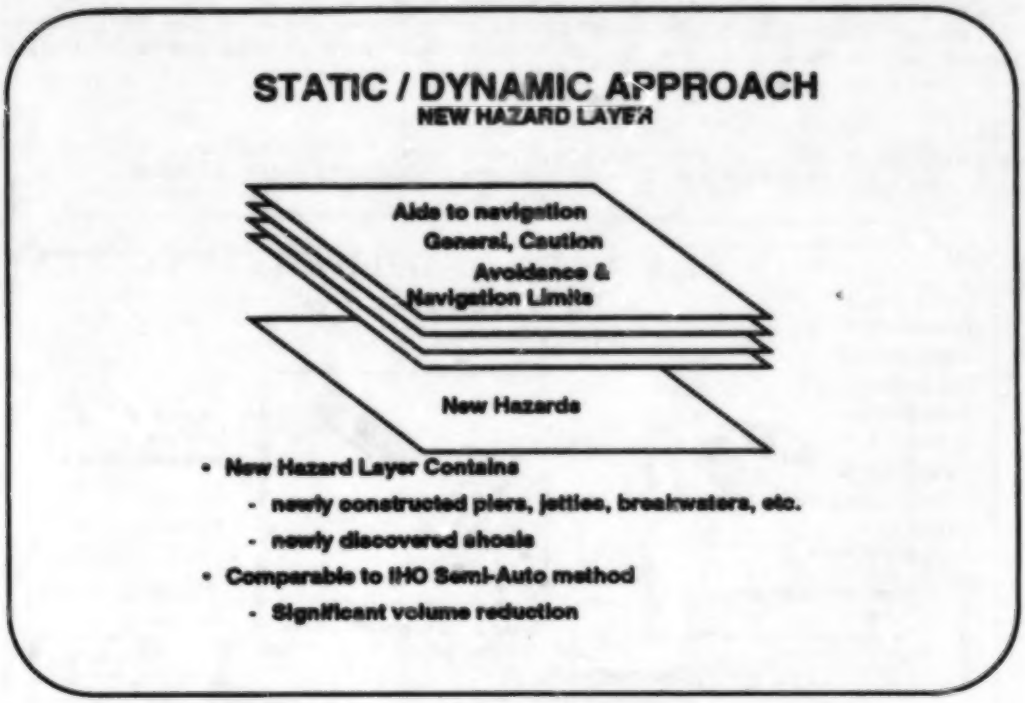
Advantages

Using this approach, no major infrastructure is required for the generation, archival, and distribution of corrections--a significant cost savings. DNCs remain current without the need for field application of corrections. Corrections are applied once by the producer, not one time per user. This should mean improved currency and performance, increased data integrity, reduced costs, and lessened complexity for both the ECDIS development and operation.



Disadvantages

On the downside, two immediate problems come to mind. Isn't it costly to press and distribute new CDs every week? We believe it is no more costly than weekly distribution of corrections via broadcast or on other hard media such as floppy disc. What about the remaining 10 percent of corrections that apply to the Static information? How will they be handled? It is our belief that corrections of this type, which are important to distribute to the user, are new construction; i.e., piers, jetties, breakwaters, etc. They will be carried in a special layer called "New Hazards."



They will be displayed as other data, possibly in a different color so that extra caution can be taken. When new editions of the static information are made, the New Hazards' information will be applied, and the static layers will once again be current.

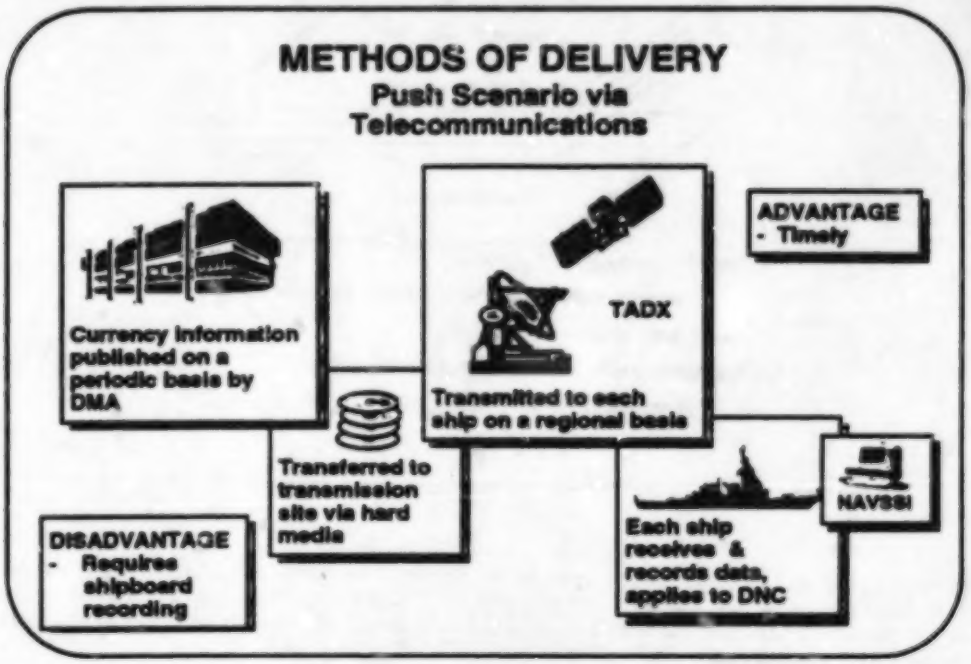
This approach is still in the conceptual stage. No decision on which method for keeping DNCs current has been adopted.

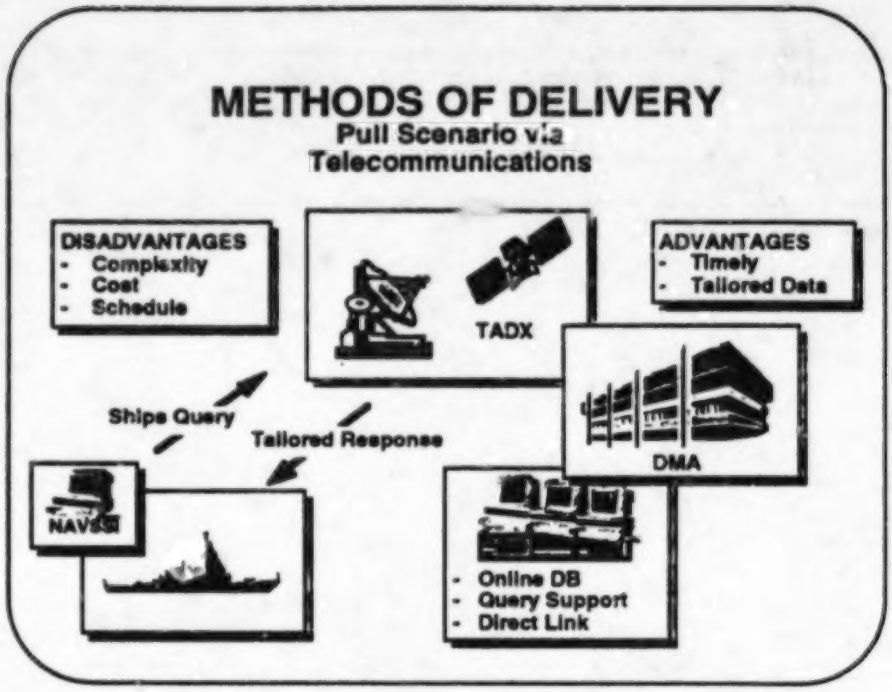
METHOD OF DELIVERY

The above methods of application of corrective information in some cases assume method of delivery; floppy disc, CD-ROM, etc. Each of these methods is also applicable to telecommunications as a method of delivery. The advantages of delivery by hard media are that the infrastructure supporting it is relatively simple, the least costly of all methods under consideration and could be implemented the soonest. However, delivery of hard media via the US mail, as is now done for printed Notice to Mariners information, is not acceptable in a digital environment.

For delivery to Navy customers, telecommunication of the data is preferred. Existing or planned Navy telecommunications systems, such as the Tactical Data Information Exchange System (TADIXS) or Global Grid, offer the potential for more timely delivery.

Via telecommunications, two scenarios are under consideration, a "push" and a "pull" method. Both scenarios are notionally shown in the figures.





Either could be successfully implemented; the method for implementation is a function of the requirements, cost and schedule. It is likely that a "pull" scenario, while potentially the more elegant solution, might not be implementable in the near term due to its increased complexity.

IHO/IMO COMPLIANCE

Some may feel that DMA's approach to DNC development has put us at odds with the IHO and the IMO concept. While the Navy developmental effort is being designed to comply with those organizations proposed standards for performance and data content, chart data will be transferred to DoD users in VPF rather than the IHO-/IMO-preferred standard, DX-90. This was necessary, in our view, because Navy systems are being designed for requirements beyond navigation; command and control functions, mission planning, and weapons system support. These additional requirements demand interoperability with other DMA data sets; e.g., digital Topographic Line Maps, Tactical Terrain Data, World Vector Shoreline, etc. We felt that a single standard was best for DoD. We chose VPF as that standard. It is our opinion that VPF and DNCs will satisfy the performance and content requirements for ECDIS.

CONCLUSION

The U.S. Navy and DMA are committed to the development of a Navy ECDIS using standard DMA products with the goal to provide a digital replacement for the paper nautical chart by the year 2000.

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